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TEST METHODS AND RESULTS OF A STUDY OF GREASES FOR USE IN ROTO-LAUNCH VALVE LUBRICATION

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The extended use of a MIL-G-23549 grease for lubrication of a roto-launch valve maintained at a temperature of 700°F caused a significant lubrication problem. This was brought about by decomposition of the grease into a solid mixture of molybdenum disulfide and clay which would clog grease lines in the vicinity of the valve. As an approach to this problem, several alternate grease formulations capable of providing lubrication under high load conditions were evaluated for their tendency to decompose at high temperatures.

Testing was done by measuring the adhesion of grease residues to a steel surface and by measuring the amount of pressure required to force grease through a test rig maintained at 700°F. These studies indicated that the use of alkly-urea thickeners in place of clay thickeners decreases the tendency of a grease to clog grease lines under high temperature conditions.

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BACKGROUND

Reports from the fleet indicated problems with the use of MIL-G-23549 grease for lubrication of a roto-launch valve in an advanced aircraft carrier catapult system. Temperatures in the vicinity of this roto-launch valve approach or exceed 700°F and this results in decomposition of the grease to form a hard dark deposit both in the grease lines leading to the valve and in channels within the valve. This build-up of deposit was reported to interfere with lubrication. Since this command is responsible for the MIL-G-23549 specification, it was tasked by reference (a) to aid in the selection of a suitable high temperature lubricant for this application.

Lubrication requirements for this roto-launch valve are stringent and require a grease having a high temperature capability and good load carrying capacity. MIL-G-23549 was selected on this basis. This grease is essentially a suspension of powered molybdenum disulfide (MoS_2) and clay in a mineral oil base. In view of the grease composition, it is suspected that the dark hard deposit noted by the fleet would consist of a mixture of MoS_2 and clay formed by oil decomposition or evaporation. Possible solutions to this problem might involve using a grease made from a more viscous oil or a synthetic oil to reduce thermal degradation/evaporation, or using a grease containing reduced amounts of solids in order to decrease the rate of deposit build-up.

APPROACH

Several greases of various compositions were screened in this laboratory in order to determine if any other type of grease would be better suited for this application. These greases included several clay-thickened greases, two alkyl-urea thickened greases and a polyperfluoroethylene based grease. This initial screening test was designed to measure the strength of adhesion of grease decomposition products to a steel surface. The assumption in this test is that greases that produce thermal degradation products having weak adhesive characteristics would have less tendency to clog grease lines than those greases whose degradation products adhere strongly to steel surfaces.

The test configuration used in this preliminary evaluation of greases is shown in Figure 1. In this test, a thin film of grease (B) is spread between two steel plates (A), and this sandwich arrangement is baked in an oven at either 500°F or 700°F for several hours. Heat exposures at these temperatures solidified the grease and effectively bonded one steel plate to the other. After allowing this configuration to cool down to room temperature, the adhesion of these various grease residues to a steel surface was determined by measuring the force required to break the bottom plate free of the top plate. These measurements were made by holding the test configuration in clamp (C) or by other suitable means and successively loading the bale rod (D) in one pound increments to failure.

After preliminary screening, selected lubricants were tested under condititions that more closely reproduced roto-launch valve conditions. This

test rig is shown in Figure 2. This test rig consists of a 2" x 2" x 4" steel block (A) modified to include a 1/4" grease channel (C) that was designed to approximate conditions in the grease lines close to the roto-valve and a 1/8" x 1/16" groove that would approximate the grooves on the roto-valve. In testing, base plate (F) is fastened to block (A) and grease is pumped through grease fitting (B) into channel (C) and through groove (D) until a solid ribbon of grease exits from outlet ports (E, E'). This test rig is loaded using a special grease gun fitted with a 10,000 PSI pressure gauge. This pressure gauge measures the pressure necessary to initially pump grease through the clean test rig and the pressure necessary to pump grease through the test rig after baking the rig for a selected temperature and time. It was observed that grease solidification and clogging in the test rig could be detected as a substantial increase in pumping pressure.

RESULTS

The composition of the greases used in the preliminary evaluation are listed in Table I. The primary intent of this evaluation was to compare the effect of alkyl-urea thickeners against the effect of clay thickeners on the adhesiveness of the grease residue. All data in Table I, except column 1, represents the average of two determinations. Although this type of test data would not be expected to be highly precise, several interesting trends can be seen. First, it was observed that strongly adhesive grease residues form at temperatures as low as 500°F and, secondly, that alkyl urea thickened greases produce a residue that is less adhesive than clay thickened grease residues. On the average, approximately 10 pounds of force was required for clay thickened greases as compared to the 5 pounds of force required for alkyl-urea thickened grease. The tetrafluoroethylene polymer grease seemed promising since only 4 pounds of force could separate the two plates. However, because this grease could produce toxic decomposition products at these temperatures, no further testing was done.

Examination of the residues on failed metal panels suggest that the mode of failure for clay thickened greases might be significantly different than alkyl-urea thickened greases. A sketch of the appearance of the residues of clay and alkyl urea greases on failed panels is shown in Figure 3. The failure mechanism of the clay thickened grease appears to be an adhesive type failure since it was noted that the residue peeled away from the surface of the panel leaving numerous patches of bare metal showing through the black, slightly oily residue film. In the case of the alkyl urea grease, both panels that formed the initial sandwich configuration were covered with an even deposit of a light brown residue. Since this residue film did not show any tendency to peel away from this surface of the panel, a cohesive failure is suggested. It is probably safe to assume that these residues are composed of thickener, MoS_2 and possibly other additives and would be the result of oil evaporation. The test configuration in Figure 1 would effectively prevent oxygen from reacting with the grease residue. Another type of residue caused by oxidative degradation of the grease was noted around the edges of the panels. This residue had a charred appearance and was very hard. The differences in

these two types of residues was most apparent during solvent cleaning of used panels. The clay and alkyl-urea grease residues that were protected from the atmosphere were easily removed by scrubbing with an organic solvent, whereas, the charred residue was not affected by the solvent.

These initial results indicated the possibility of substantial differences in alkyl-urea grease when compared with clay thickened greases. This suggests that further testing of these greases should be made under conditions that more closely simulated conditions at the roto launch valve. This testing was done in the grease rig shown in Figure 2. The final testing was limited to two clay thickened greases and one alkyl-urea grease that were qualified under the MIL-G-23549 specification. The composition of these greases and test results are shown in Table 2.

Approximately 350-500 PSI was required to initially pump the grease through the test rig shown in Figure 2. This pumping pressure was considered as a base line value. After initially baking the grease in the test rig for 24 hours in an oven set at 700°F, it was found that only 500 PSI was required to regrease or refill the test rig. Since this pressure was not significantly greater than the initial pumping pressure, it was assumed that no significant amount of grease solidification had taken place within this time period. After 48 hours, one of the clay thickened greases required 1200 PSI pressure during regreasing of the test rig. Two other greases in Table 2 showed a slight increase in pumping pressure. After 72 hours, all greases except the alkyl-urea grease showed a significant increase in pumping pressure. After 96 hours, two of the greases tested showed a drop in pumping pressure from the preceding day. This was the result of dislodging some of the grease residue from the grease line. After 120 hours, all greases required an elevated pumping pressure. In this test, the criteria for failure is the amount of time that a grease formulation can survive at an elevated temperature without significant decomposition. A pressure of 1,000 PSI was arbitrarily chosen as indicating significant grease decomposition in the test rig. According to this criteria, the two clay thickened greases failed within 72 hours, whereas the alkyl-urea grease failed at 96 and 120 hours in duplicate tests.

A sketch of the type of deposit found in the bottom groove or channel of the test rig is shown in Figure 4. It was found that the grease residue initially formed along the sides of the channel. After several days, it was found that this residue build-up was severe enough to leave only a small passageway for grease flow. Examination of this residue indicates that it was a dark oily grandular material that could be easily broken down into smaller particles. Near the exit port, the grease residue was a whitish ash-like material. It is doubtful if this later material would offer much resistance to grease flow. It was noted that the grease path through the residue was wider in some parts than in other parts. This suggests that the pressure drops noted in Table 2 were due to the breaking off of residues that formed constrictions in the grease channel.

CONCLUSIONS

The grease solidification process that has been observed in the roto-launch valve assembly has been successfully duplicated in the laboratory

using a newly developed test rig. Visual observation of the grease solidification process in this rig suggests that solidification initially occurs on the walls of the grease channel and that the solid grows radially outwards so as to severely restrict grease flow. It has been observed that alkyl-urea thickened greases were superior to clay-thickened greases in retarding the build-up of solids.

FUTURE PLANS

It is conceivable that more frequent relubrication would have a beneficial effect on retarding the build-up of residue deposits. Further testing will be done using a 6 hour/16 hour bake cycle to see if shorter time intervals would retard deposit formation. The results of a more frequent lubrication cycle on deposit build-up will be reported at a later date.

REFERENCES

(a) COMNAVAIRSYSCOM Washington DC msg 13226Z Jun 1980

TABLE 1. Results of Preliminary Screening of Candidate Grease Formulations

Sample Identification		Force Required to Separate Plates (Lbs)			
I.D.	Composition	16 Hrs/ $500^{\circ}F$	2 Hrs/ $700^{\circ}F$*	17 Hrs/ $700^{\circ}F$*	Average Value
A	Mineral Oil + Clay + MoS_2	15.5	8.0	4.5	9.3
B	Mineral Oil + Alkyl-Urea + MoS_2	4.5	3.5	6.5	4.8
C	Mineral Oil + Clay + MoS_2	17.0	8.0	6.5	10.5
D	α-Olefin +Clay + MoS_2	12.0	11.0	8.5	10.5
E	α-Olefin + Alkyl-Urea + MoS_2	-	-	7.5	7.5
G	Fluoroethylene Polymer	-	-	4.0	4.0

* Results are the average of two separate determinations

TABLE 2. High Temperature Clogging Tendencies of Selected Greases

Sample Identification		Grease Pumping Pressure (PSI)*				
I.D.	Composition	24 Hrs	48 Hrs	72 Hrs	96 Hrs	120 Hrs
A	Mineral Oil + Clay + MoS_2	500 500	600 1200	1200 2400	600 1200	2400 2400
B	Mineral Oil + Alkly-Urea + MoS_2	500 500	500 500	500 500	600 1000	2000 1000
C	Mineral Oil + Clay + MoS_2	500	600	1800		

* Maximum pressure noted in grease line during initial lubrication or relubrication of test rig.

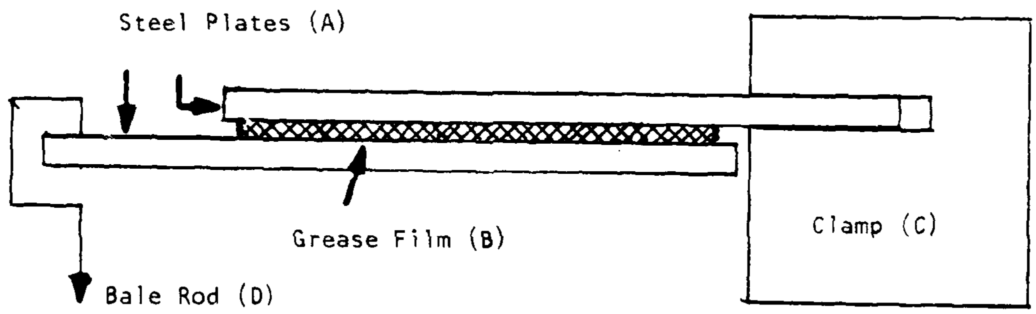

FIGURE 1. Test Configuration Used for the Preliminary Evaluation of Greases

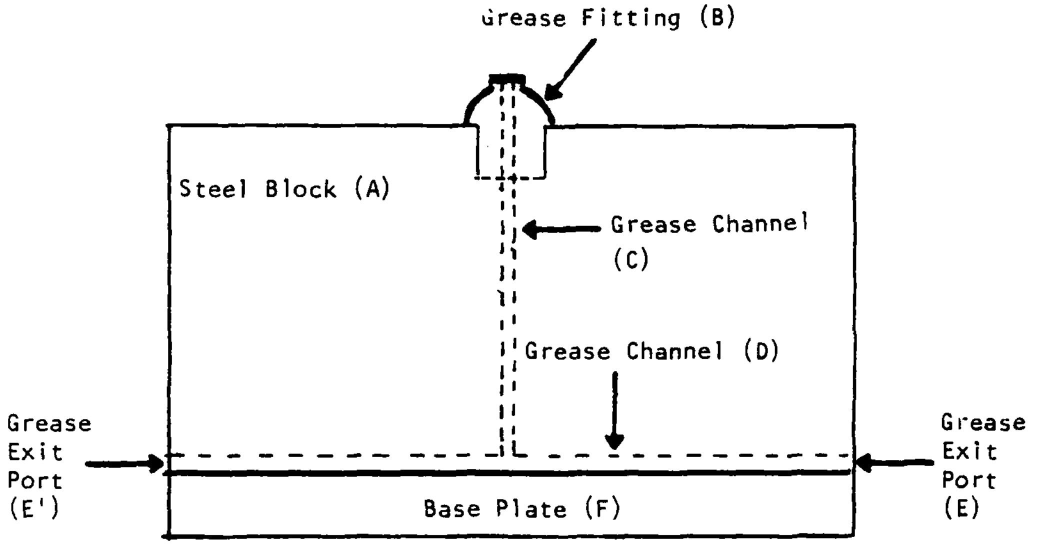

FIGURE 2. Testing Rig Used for Measuring Grease Solidification Properties

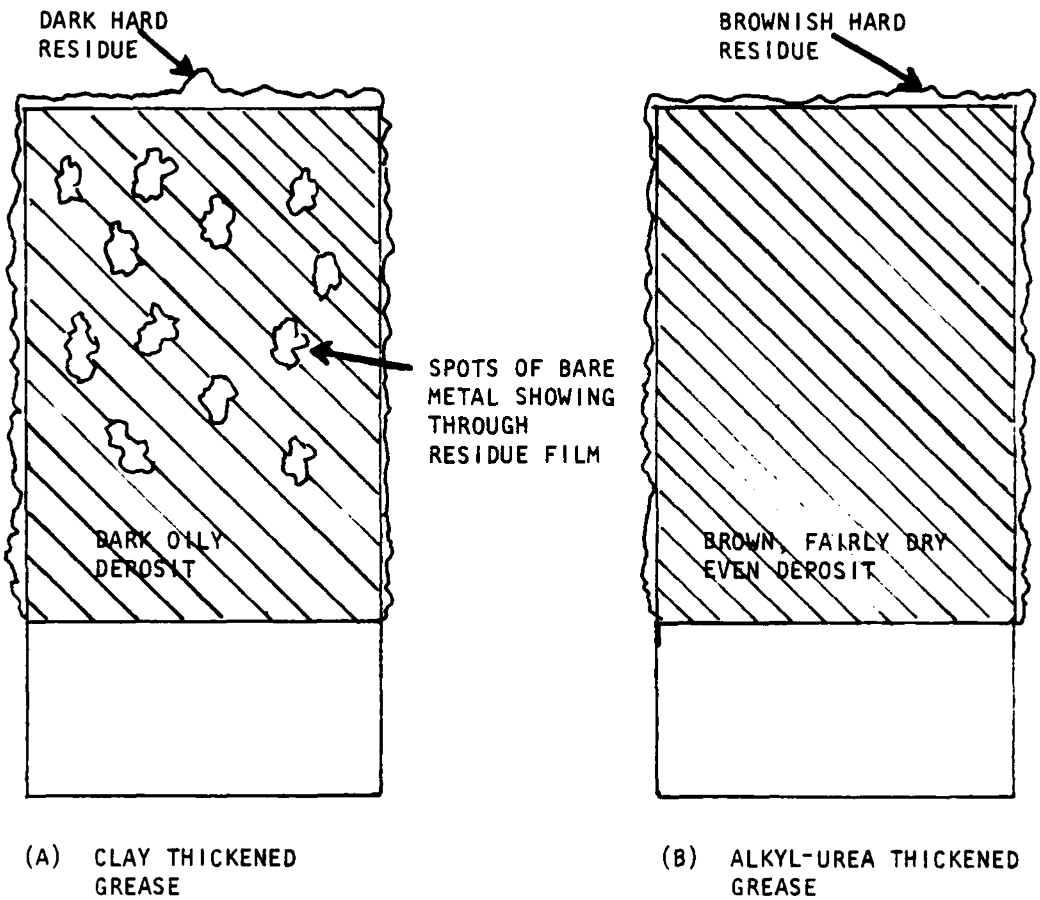

FIGURE 3. The Appearance of Grease Residues on Failed Steel Panels

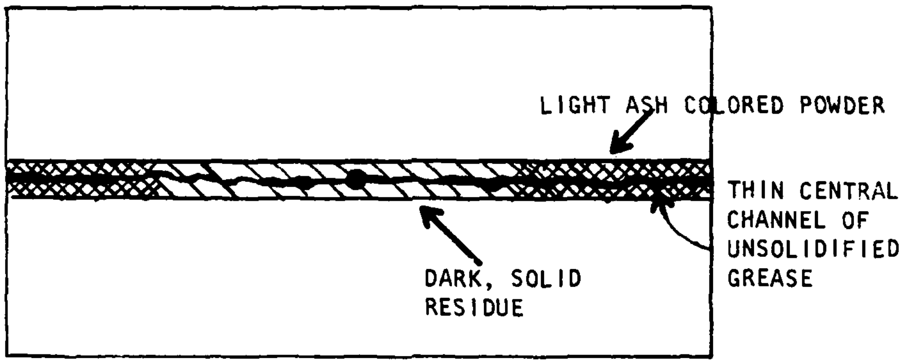

FIGURE 4. The Appearance of Groove on Bottom of Test Rig after Heating for Several Days at 700°F

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